THE HABITS OF THE FISHES OF INLAND LAKES[1]

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AGRICULTURE has progressed to the point where a farmer can readily secure reliable scientific advice as to what crops are adapted to his grange. Such counsel is usually based on studies concerning climate, soil analysis, bacterial counts, depth of water table, prevailing pests, and other factors. Scientific aquiculture is far behind agriculture, and those who attempt to harvest crops from the water must proceed without much help from science. During the past few years there has been a quickening of interest in aquiculture in the United States, and attempts are now being made by commercial and scientific men to increase the yield from fresh water. The Bureau of Fisheries is constantly increasing the production of our inland waters by improving methods of propagation and by exploiting new sources of food. Professor E. A. Birge is making notable scientific contributions concerning the conditions in lakes and their value as habitats for fishes. Professor S. A. Forbes has made similar studies relating to rivers, and also published eminent works on our fresh-water fishes. Recently Cornell University has established a course in aquiculture for the purpose of training young men to take up aquatic farming. Several commercial fish hatcheries, which have relations to aquiculture comparable to the seed houses in their relations to agriculture, are now successfully rearing trout and other fishes to be sold for stocking purposes. At Oshkosh, Wisconsin, Mr. C. B. Terrell operates an enormous aquatic farm in the swamps around Lake Buttes des Morts and does a thriving business in aquatic plants and seeds. He also gives advice to fish culturists, game clubs, and others interested in aquiculture as to how to set out and harvest crops of aquatic plants, fishes and fowls.

The writer has been attempting to solve three fundamental problems relating to aquiculture—(1) why certain species of fishes are abundant in some localities and not in others, (2) why a certain kind of fish may reach maximum size in one body

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of water, but remain small in another, and (3) how many fishes a body of water may support. The present paper summarizes studies made during the past five years in the inland lakes of Wisconsin.

In order to determine which species of fishes were most abundant in these lakes and which habitats were most densely populated, two years were spent in general collecting, and all the methods commonly employed by fishermen were used (spear, dip net, gill net, seine, hook). About 1,700 fishes of 33 species were collected, and the following information, which of course relates primarily to lake fishes, was secured:

1. *The important factors in the selection of habitats are associated with food, shelter and breeding.* Food is more important than shelter, for there are more species and individuals in situations with much food and little shelter than in those with abundant shelter and little food. More fishes are found in the shore vegetation, which furnishes both food and shelter, than in any other habitat. Breeding activities dominate all others at certain seasons, there is then usually more or less fasting and disregard for usual protective measures, but this condition lasts only for a short time and the major activities of a fish are usually devoted largely to seeking and securing food.

2. *Each species of fish selects particular foods from those available.* Though different kinds of fishes often feed on abundant available foods, each has its preferences—fishes are not indiscriminate feeders. For example, on July 3, 1915, fishes of about the same size and belonging to four different species[2] were taken in a single short haul of the net. Ten fishes of each species were examined and striking differences were found. The black bass had taken 21 different kinds of food; the bluegills, 16; the shiners, 14; and the top-minnows, 11. The particular item of food taken in largest amount by each species was as follows: black bass, 25 per cent. damsel-fly nymphs; bluegill, 47 per cent. cladocerans (*Eurycercus*); top-minnow, 49 per cent. amphipods; shiner, 43 per cent. Daphnia. All the species had eaten *Eurycercus*, which must have been abundant, but only a single one had eaten damsel-fly nymphs or daphnias. Many other facts show that competition between different species for particular foods is usually not very keen.

3. *The most important foods of the lake fishes are: insect*

[2] The scientific names of those were *Micropterus salmoides* (Lacépède), *Lepomis incisor* Cuvier and Valenciennes, *Notropis heterodon* (Cope), *Fundulus diaphanus menona* Jordan and Copeland.

larvæ and pupæ, microscopic crustaceans, fishes, amphipods, plants, bottom ooze, molluscs, and crayfishes. Young fishes feed largely on insect larvæ and microscopic crustaceans. Though some fishes eat the same kinds of food throughout life, adult fishes have rather specific feeding habits (the bass prefer insects; the sheepshead, molluscs; the pike and gar, fishes; the darters, midge larvæ; the silversides and cisco, micro-crustacea; the bullhead is omnivorous).

4. *The most abundant fish of economic importance in the large, deep lakes studied was found to be the yellow perch; in the smaller lakes the perch were also abundant, but the black crappie and two sunfishes were also present in considerable numbers.*

After these preliminary studies the perch and crappie were selected for careful investigation, the first being the most abundant and representative fish in the large, deep lakes, and the latter appearing to thrive best in small, shallow lakes. The food, migrations and breeding were studied. During this work at least ten individuals were usually examined every week for a year. The perch were studied carefully in two lakes: Mendota (7 miles long, 84 feet deep) and Wingra (1 mile long, 12 feet deep), but weekly examinations of the crappie were made only in the latter.

The perch is probably more abundant than other species of food fishes because it is more versatile. It feeds among the shallow-water vegetation on insect larvæ, fishes, snails, and other shore foods; it digs out the abundant larvæ and clams from the soft sedimentary deposits in deep water, and even feeds on the ooze itself; with its slender gill rakers, it strains plankton organisms from the open waters. It can compete with the basses, sunfishes, gars, pikes and bullheads which run along the shore; it does as well in the open lake as the specialized ciscoes, and is able to share the deeper waters with suckers and lawyers.

It is easy to see why perch are abundant, but when we try to understand why they have a characteristic maximum size in different lakes, the problem is somewhat more difficult. The investigation of differences in feeding or available food supply offered one probable field which might throw some light on the question. However, the food of the perch in the two lakes investigated was found to be much the same. Fishes, insect larvæ, and some other items were eaten in somewhat larger quantity in Lake Wingra, but that would be expected because

there was proportionately more of shore habitat. The important foods were abundantly present in both lakes and enough difference in the quality of the foods eaten was not found to account for the constant difference in the size of the fishes.

One fact was noted, however, which gave a clue for further work. The perch in both lakes were often found to be empty during the breeding season, and this was easily accounted for by supposing that the excitement incident to the mating activities led to neglect of feeding. At all other seasons the perch in Lake Mendota were stuffed with food. Those in Lake Wingra, however, were often *empty during the warmer parts of the summer.* This difference between the two lakes led to the conclusion that the smaller size of the perch in Lake Wingra was due to the fact that there was less opportunity to feed in the small, shallow lake. This view was supported by other evidence. For example, during windy weather, more perch could be caught in Lake Wingra with hook and line from a drifting rowboat than in a gill net, while the opposite was true on quiet days. The perch were present and ready to feed, but did not move about much when the water was disturbed.

To test the opportunities for feeding in the two lakes it was necessary to study the migratory activities of the fishes. The comparative distribution of fishes at different times was judged by the catch per hour in gill nets of standard size. The nets were set simultaneously at various depths and comparisons could thus be made. The perch remained in the deeper parts of the lakes, except for two or three weeks during the breeding season. There was a slight migration into shallower water at night.

In late summer a fish can not remain permanently in the deeper waters of Lake Mendota because the thermal stratification of the lake causes the lower water to stagnate. During August, September and October the water below thirty or forty feet contains no oxygen. It was noticed, however, that, though perch were most abundant just above the level where oxygen disappeared, often when nets were set below a number would be caught. There are enormous quantities of food in the stagnated region[3] and, if perch are able to go down there for food, they can draw on supplies which other species of fishes can not attain. The only other fishes caught in deep water were occasional suckers.

[3] Recent unpublished investigations by Birge and Juday show that there may be as many as 18,000 midge larvæ per square meter in the mud at the bottom of Lake Mendota.

At first the catches of perch in deep water during the period of stagnation were thought to be "accidental," but they recurred with such regularity that tests were finally made to see if the fishes were able to live without oxygen. Perch were enclosed in wire cages and let down on lines into the stagnant water. Most of them lived for an hour without apparent difficulty and many survived for two hours. In considering how they were able to live in water without oxygen for such a long time the possibility of the use of gas reserves in the swim bladder was suggested. The content of the swim bladder in normal perch was found to be about 63 per cent. nitrogen, 36.8 per cent. oxygen, and 0.2 per cent. carbon dioxide. After a perch had remained in the stagnant water for an hour the oxygen decreased to about 20 per cent., showing that the swim bladder serves as a reservoir for oxygen which may be used when the fish is in stagnant water.

All these things have some relation to the differences in size between the perch in the two lakes under consideration. The supposition that the perch in Mendota are larger because they have better opportunities for feeding appears to be justified. To state the case briefly, the perch in Lake Wingra do not feed during very hot weather, probably because the shallow water all becomes warm, nor are they able to feed readily when the wind blows because the water is all disturbed; but the perch in Lake Mendota can feed at all seasons because they may always retreat into the cooler depths to escape heat and the disturbances due to wind, and, as they are able to live for some time in water without oxygen, they may utilize the abundant food in the deeper water without danger of suffocation.

After some idea had been gained as to why the perch are larger and more abundant in Lake Mendota than in Lake Wingra, an explanation was sought as to why crappies were more abundant in the latter. It is well known that crappies are suited to shallow muddy waters, but, so far as I know, no one has ventured to state why. In the present investigations it is apparent that more crappies are to be expected in Lake Wingra because there is proportionately more shallow water. In this lake perch and crappies live together; the former does not do very well, but the latter is highly successful. When the food, migrations, and breeding habits are compared the reasons for the differences become apparent.

The food of the crappie is more limited in range than that of the perch—less variety is necessary; the feeding takes place

largely at night or in early morning or evening; whereas the perch feeds by day. The crappie easily finds all the food needed in shallow water among aquatic plants and it does not need to fast during hot summer days. It also breeds during July and August when the water is very warm, and apparently suffers no inconvenience in a shallow lake which becomes warm very rapidly in the spring. To summarize, the perch is a rather generalized fish of great versatility and is at its best in a large lake where there is a variety of habitats and where there is always cool water for breeding and for retreat during windy or warm weather; the crappie is a specialized fish suited to live among vegetation in shallow water, is adapted to feeding when there is little wind or heat and to breeding under conditions which would be unfavorable to most fishes.

In connection with the studies on migrations some evidence was secured which indicated that there must be a very large number of fishes in Lake Mendota and later some attempts were made to obtain approximate figures. Such estimates are highly speculative, but give some idea of the fish population a lake may support.

Most of the fishes in a lake do not stay in one locality, but keep moving about continually. There are many observations which support this view. During certain experiments gill nets were anchored in particular spots and the catch was removed from them at four-hour intervals for twenty-four hours. If the fishes were all taken ashore, just as many were caught during the next four hours as when all were thrown back. During the summer of 1917 about a thousand perch were tagged during one month. Though fishing was always done at one of three stations, only one of the tagged perch was caught a second time. Such observations give some idea of the vast numbers of perch present.

Some data have also been collected which bear on the number of perch that the available food of Lake Mendota can support. By feeding perch weighed amounts of various natural foods and noting the time required for digestion it has been determined that an average individual at 25° C. eats an amount equal to about 7 per cent. of its own weight daily. In winter (2.5° C.) digestion is only one third as rapid as in summer. Recently Dr. R. A. Muttkowski made an extensive survey of the invertebrates in Lake Mendota and has computed the numbers present in the whole lake. For example, he estimates that there are enough chironomid larvæ in the lake to feed 16,675,447

perch to capacity each year. This single instance gives some idea of the capabilities of a lake seven miles long and four miles wide as a source of food.

In order to discover how many fishes were taken from Lake Mendota, statistics were collected from fishermen. The number of men fishing each day was counted at different seasons and their catch per hour ascertained. By compilations from such data it is estimated that 424,540 perch are caught each year. Computing from the comparative catches per hour in gill nets (a method open to certain obvious errors) the numbers of other species caught would be: pickerel, 2,208; bluegill sunfish, 1,238; white bass, 615; rock bass, 613; pumpkinseed, 428; large-mouth black bass, 305; silver bass or crappie, 183. Probably none of these numbers is too large and some are undoubtedly too small. They at least give some notion of the capacity of an inland lake for producing fishes. It is hoped studies now in progress will give more definite information.

Perhaps only one conclusion is justified from the observations discussed in this paper—aquiculture is certainly a promising field for research and commercial development. Scientific men may profitably attack the many problems to be solved with reasonable assurance of results of importance to science and to the welfare of the human race. Those interested only in the economic aspects of aquiculture may also look for increasing rewards as aquatic farming develops.